Viticulture, enology and marketing for cold-hardy grapes

Leaf Injury Associated with Copper and Sulfur in Northern Grape Varieties: Preliminary Assessment

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Topics

- Role of copper and sulfur for disease control in grapes
- Forms of copper and sulfur, how they work, and how they injure plants
- Northern Grapes Project disease management research—preliminary findings

Copper and Sulfur

- Among the oldest fungicides and still among the most important
  - Homer refers to “pest-averting” quality of sulfur in 1000 BC
  - Bordeaux mix developed in 1800s, first used to control grape downy mildew
- Phytotoxicity has long been recognized as a problem
  - J.G. Horsfall, 1945: “Copper and sulfur may be expected to act unexpectedly”

Role of Copper and Sulfur in Managing Diseases of Grapes

- Copper-based fungicides
  - Highly effective on downy mildew pathogen
  - Limited activity against other pathogens
- Sulfur
  - Highly effective on powdery mildew
  - Little or no activity on other pathogens
- Liquid lime-sulfur
  - Dormant application may have eradicant activity on anthracnose fungus

Role of Copper and Sulfur in Managing Diseases of Grapes

- Fungicide resistance management
  - Both copper and sulfur act by non-specific disruption of proteins
  - Still effective after centuries of use
  - DMIs, strobilurins, and SDHIs can be overcome by a few mutations in pathogens → fungicide resistance
  - Some forms of copper and sulfur cheaper than synthetic fungicides

Role of Copper and Sulfur in Managing Diseases of Grapes

- Important in organic production
  - Some forms of copper and sulfur are approved by OMRI
  - Copper and sulfur often less expensive than other OMRI-approved products

Topics

- Role of copper and sulfur for disease control in grapes
- **Forms of copper and sulfur, how they work, and how they injure plants**
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Factors Affecting Copper Efficacy and Phytotoxicity

- Amount of metallic (actual, elemental) copper
- Soluble vs. relatively insoluble (= fixed) forms
- Size of copper-containing particle or “grind”
- pH of solution
- Weather

Soluble vs. Insoluble Copper Fungicides

- Copper sulfate
  - Highly soluble in water
  - Even with relatively low amounts of copper, too much goes into solution too quickly → plant injury
  - Easily washed off by rain

Soluble vs. Insoluble Copper Fungicides

- "Fixed" copper
  - Low solubility in water
  - Spray mix is not a solution but rather a suspension of particles containing copper
  - Examples
    - Copper sulfate formulated with lime (e.g., Bordeaux), gypsum (e.g., Cuprofix), or hydroxyl ions (e.g, Basic Copper Sufate) to raise pH, reduce solubility
    - Copper hyroxide (e.g., Champ, Kocide)
    - Copper oxychloride sulfate (e.g., COCS)
    - Copper oxide (e.g., Nordox)
    - Copper ammonium carbonate (e.g., Copper-Count N)
    - Copper lineolate (e.g., TennCop)

Size of Copper "Particle"

- Lots of product literature, and some research, suggest benefits of "micronized" particles
- Smaller particles provide more uniform coverage

Size of Copper "Particle"

- Smaller particles make copper more available, so lower rates can be used
  - Less environmental risk
  - More economical, only if smaller particles don't cost a lot more than larger particles
- Less prone to wash off, therefore more persistent (which can be good or bad)

pH and Copper Solubility

- At lower pH, copper ions released from “fixed” fungicides more quickly
- Copper fungicides should not be mixed with phosphorous acid fungicides or any product that will reduce pH below 6.5
- Because some forms of copper are persistent, consider the interval between copper and PA fungicide sprays

Weather and Copper Injury

- Copper injury generally worse the longer leaves stay wet
  - Apply in lower volumes
  - Apply during dry weather

Info on Sulfur Fungicides

- *Strategic Use of Sulphur in Integrated Pest Management Programs for Grapevines*, Final Report to Grape and Wine Research and Development Corp. (Australia), by B. Emmet et al., 2003

- Wayne Wilcox's Tome on Grape Disease Management: www.fruit.cornell.edu/grape/pdfs/Wilcox-Grape%20Disease%20Control%202012.pdf

Sulfur Fungicides

- Dust
- Lime sulfur—water soluble, highly potent
- Wettable—formulated with surfactants
- Liquid flowable—homogenized and suspended in water
- Micronized dry flowable—sulfur residues infused with water and dispersants to produce an emulsion, very fine particle size (1-8 µm)

Sulfur Efficacy

- Sulfur acts via contact and vapor activity
  - Contact activity increases as particle size decreases
    - Micronized dry flowable and liquid flowable (less than 8 µm) more effective than dusts (~25 µm)
    - Smaller particles are more rainfast
  - Contact activity is not temperature dependent
  - Vapor activity, in theory, is temperature dependent, but Wilcox et al. found similar control of PM at 59 ^{o}F as 82 ^{o}F

Sulfur Phytotoxicity

- In the presence of oxygen and water, sulfur converted to sulfuric acid on leaves

$$S \rightarrow SO_2 \rightarrow SO_3 \rightarrow H_2SO_4$$

- Injury more likely at temps > 85 ^{o}F within 2 hours of application; threshold temp may be lower in humid climates
- Greater risk of phytotoxicity if particles < 1 µm because S can enter stomata

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- **Northern Grapes Project disease management research—preliminary findings**

NGP Disease Research

- Plant Pathology objectives
  - Determine relative resistance of northern varieties to diseases
  - **Determine relative sensitivity of northern varieties to copper and sulfur**
- Collaborators
  - Kevin Iungerman—Cornell University
  - Lorraine Berkett—University of Vermont
  - Patricia McManus, Dean Volenberg, Matt Stasiak, Brian Schauske—University of Wisconsin

Crop	Diseases	Rate fl. oz./Acre	Remarks
Grapes (except Concord, Concord Seedless,and Thomcord. See Precaution under Remarks)	Powdery mildew (*Uncinula necator*) Botrytis bunch rot and blight (*B. cinerea*) Alternaria rot (*A. alternata*) Rotbrenner (*Pseudopezicula tracheiphila*) Septoria leaf spot (*S. ampelina*) Black Rot (*Guignarda bidwellii*) Angular leafspot (*Mycosphearella angulata*) Anthracnose (*Elsinoe ampelina*) Leaf Blight (*Pseudocercospora vitis*)	16 - 20	For powdery mildew, begin at bud break and apply on a 10-21 day interval, making no more than 2 sequential applications before alternating to a fungicide with a different mode of action. For Black rot - begin when shoot length is 1-3 inches and continue on a 10 day interval. For all other diseases, begin applications prior to disease onset when conditions are conducive for disease. Apply Inspire Super on a 10-21 day schedule making no more than 2 sequential applications before alternating to another fungicide with a different mode of action. If disease pressure is high, use the shortest interval and highest rate. **PRECAUTION: On *V. labrusca*, *V. labrusca* hybrids and other non-viniferea hybrids where sensitivity is not known, the use of Inspire Super by itself or in tank mixtures with materials that may increase uptake (adjuvants, foliar fertilizers) may result in leaf burning or other phytotoxic effects.**

Crop injury warning for products containing difenoconazole:
Inspire Super, Revus Top, Quadris Top


Lake Superior
Canada
Lake
Huron
Lake
Michigan
Lake Ontario
Lake Erie
United States
km
0
50
100
-90°
-88°
-86°
-84°
-82°
-80°
-78°
-76°
47°
46°
45°
44°
43°
42°
41°

Product (a.i.)	Rate per acre	Rate a.i. per acre	Dates applied
Champ WG (copper hydroxide)	4 lb	3.1 lb copper hydroxide (= 2 lb copper)	May 22 June 4 and 22 July 4 and 18 August 6
Microthiol Disperss (sulfur)	10 lb	8 lb sulfur	May 22 June 4 and 22 July 4 and 18 August 6
Inspire Super (difenoconazole + cyprodinil)	20 fl oz	0.114 lb difenoconazole	June 4 and 22 July 4

Temperature at time of application < 70 F, except 79 F on July 4
Maximum daily temps <82 F, except 90 F on July 4

Data Collection

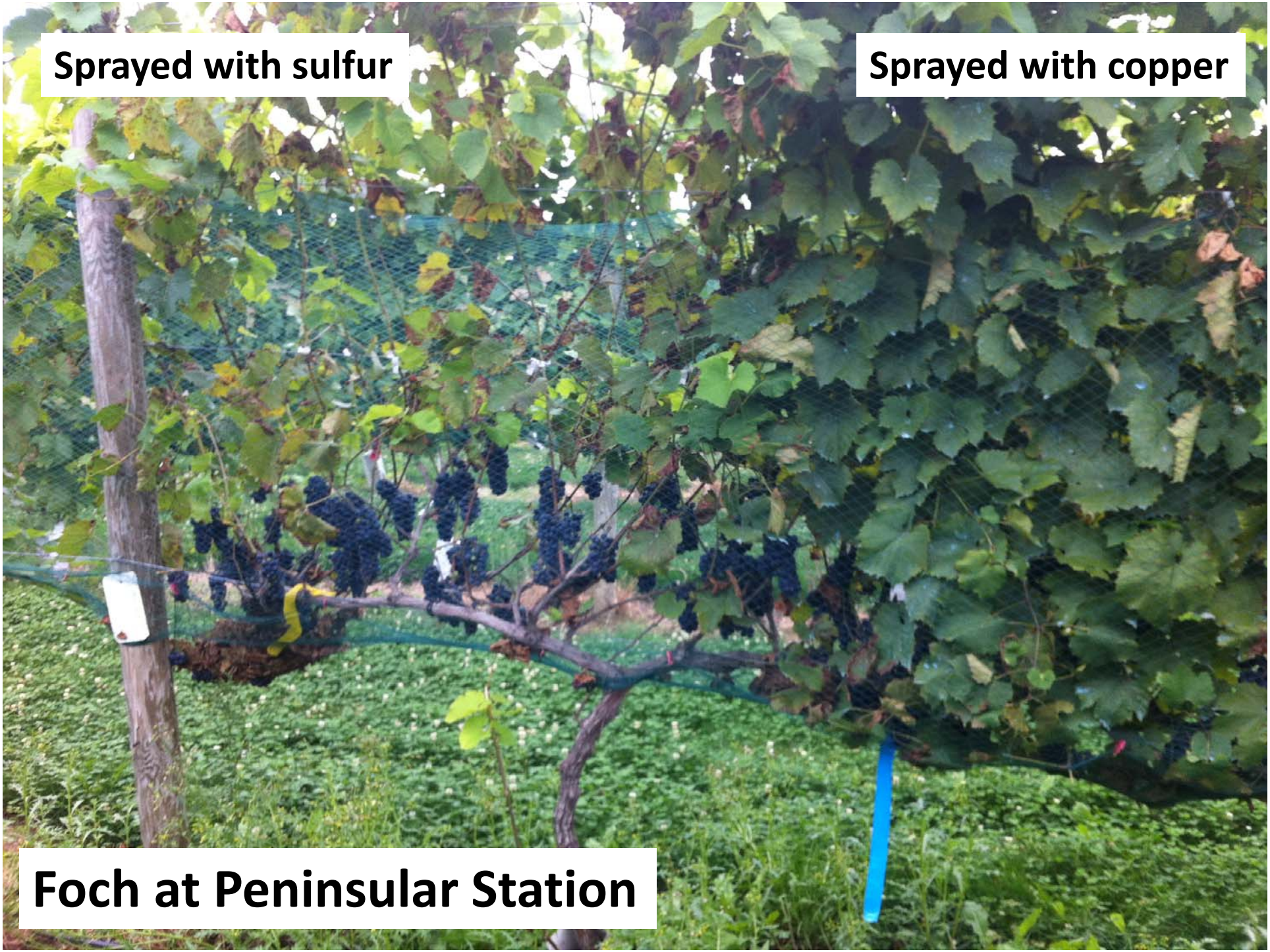
- About every 2 weeks, vines assessed for injury

  1 = no visible injury

  2 = minor injury

  3 = moderate injury

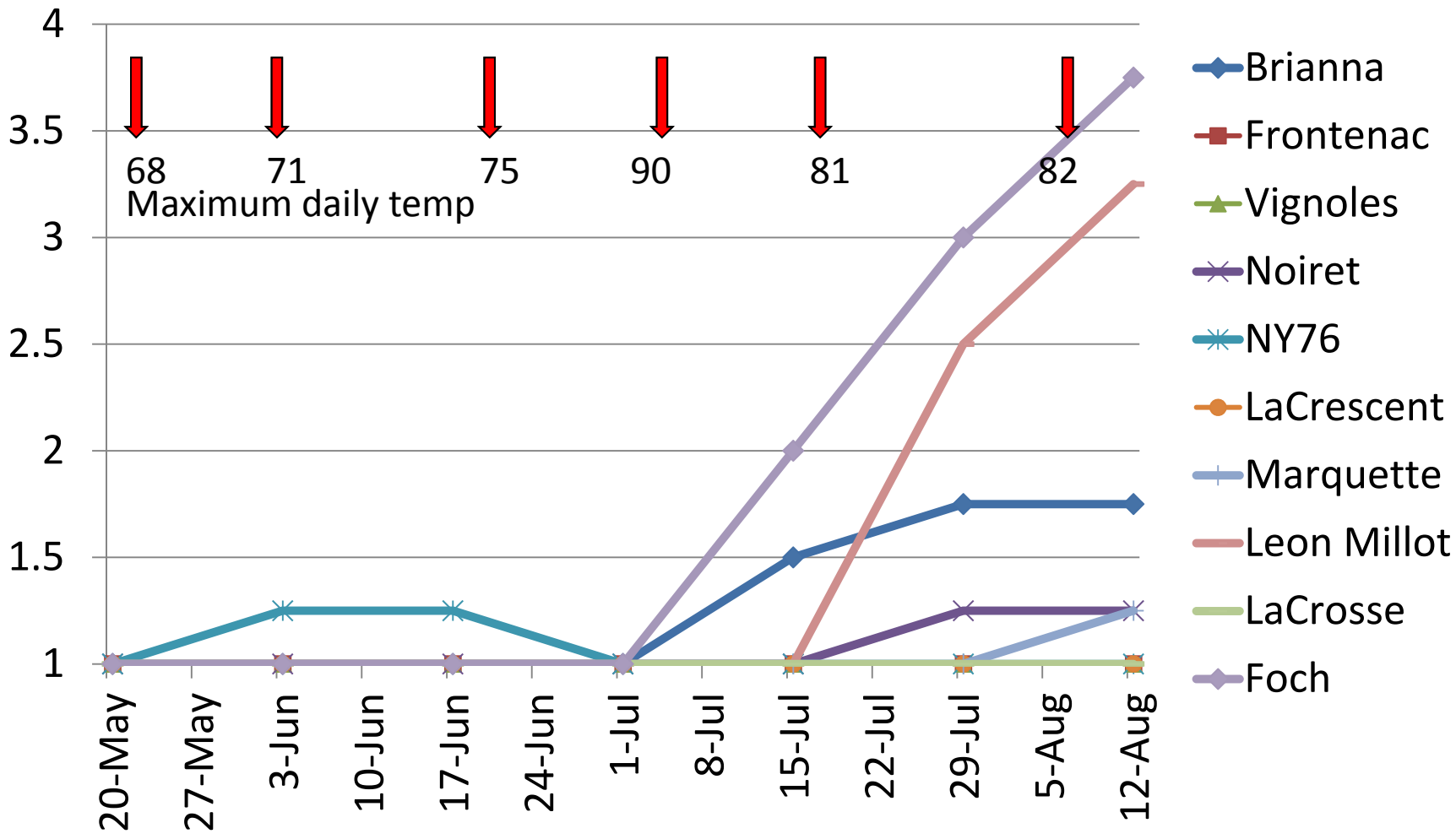
  4 = severe injury
- Same person did ratings weekly season-long
- Second person did two ratings, as a check on first rater


Sprayed with sulfur
Sprayed with copper
Foch at Peninsular Station

Copper injury on Brianna


Preliminary Data

Sulfur toxicity on grape leaves at Sturgeon Bay, WI, 2012
1 = no injury; 4 = severe injury



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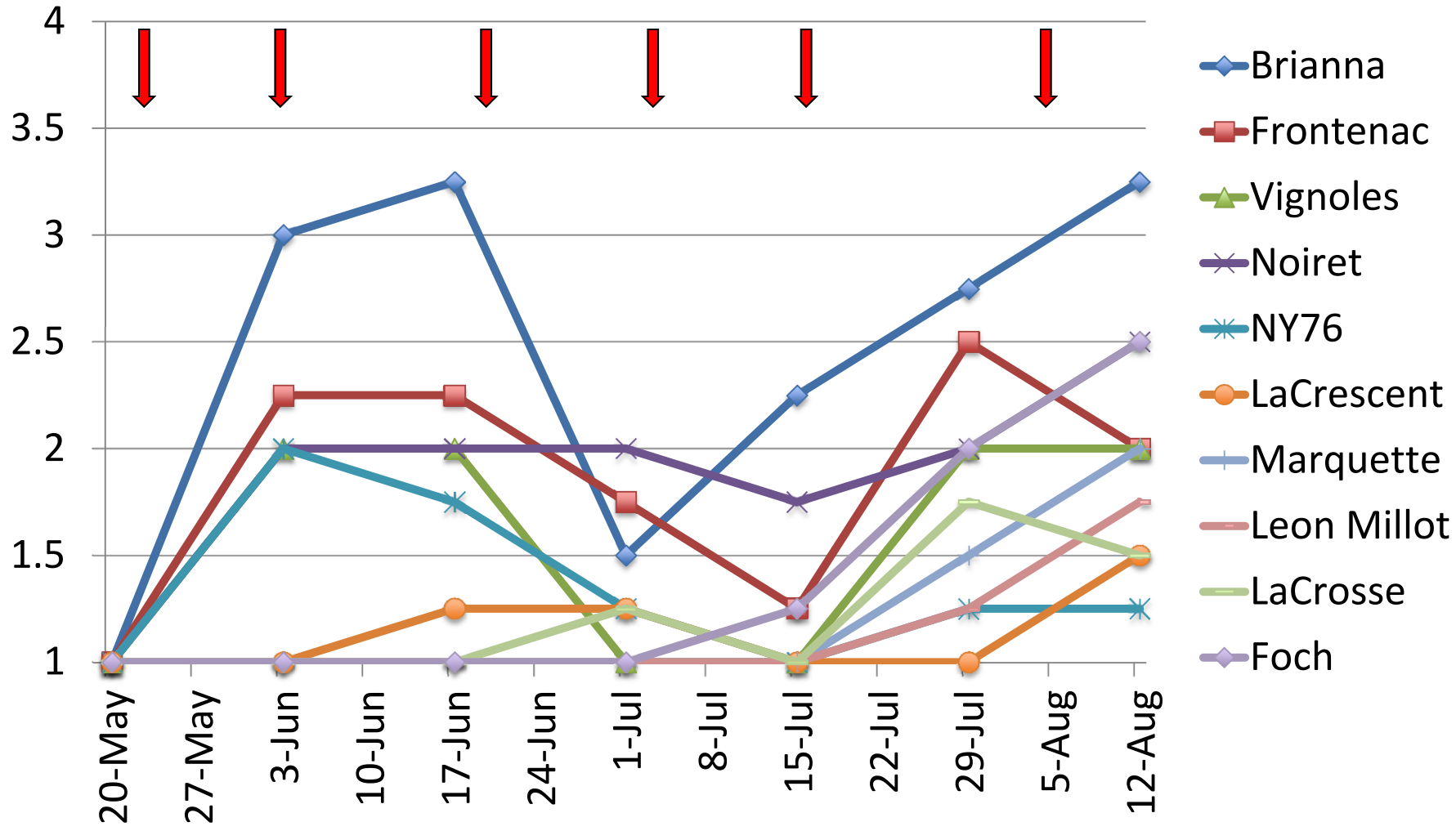

Inspire (difenoconazole) toxicity on grape leaves at Sturgeon Bay, WI, 2012
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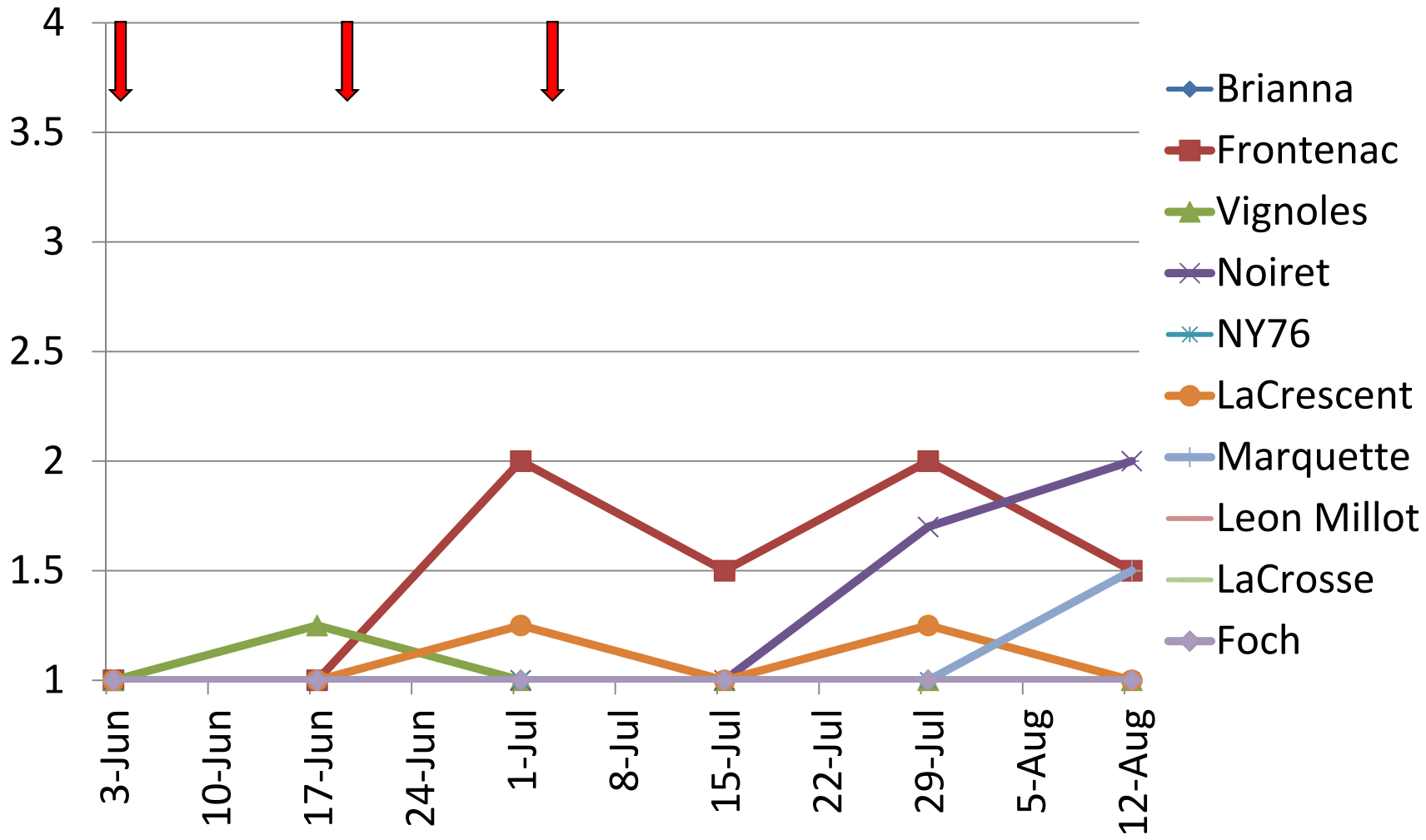

Next Steps

- Repeat over years, sites, additional cultivars
- Your comments, suggestions welcome!
  - psm@plantpath.wisc.edu
  - (608) 265-2047

Copper and Sulfur Fungicides

- Inhibit fungi on surface of plants
- Mode of action probably by denaturating proteins
- Non-selective, so also denatures proteins in plants
- Plants somewhat protected by cuticle, bark
- Fungicidal efficacy vs. plant injury balancing act

2012 Research: Leaf sensitivity to copper, sulfur, and difenoconazole

- Peninsular Agricultural Research Station (Sturgeon Bay) vineyard established in 2008
- 10 varieties replicated 4 times
- Fungicides applied at about 2-week intervals with a handgun sprayer to “run-off”
- Vines observed season-long for injury and/or discoloration